SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

      BE IT KNOWN THAT WE, TADASHI ARAKI, a
citizen of Japan residing at Kanagawa, Japan and GUAN
HAIKE, a citizen of Japan residing at Kanagawa, Japan
have invented certain new and useful improvements in

  IMAGE DISTORTION CORRECTION APPARATUS, DISTORTION
    CORRECTION METHOD THEREFOR, RECORDING MEDIA,
    IMAGE SCANNER AND IMAGE CONSTRUCTION APPARATUS

of which the following is a specification:-

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to
an image processing apparatus, and more particularly
5   to an image distortion correction apparatus, an
image distortion correction method therefor,
recording media, an image scanner and an image
construction apparatus, in which a distorted part of
a scanned image is corrected.

10   2. Description of the Related Art

When a book type original, for example, a
book or a booklet, is copied or scanned, it is hard
to keep a binding part of the book on a focus plane
of a copier or a scanner. The binding part of the
15   book type original is separated from the focus plane
of a copier or a scanner. This causes a copied or
scanned image to be distorted and sharpness of
characters on the copied or scanned image is reduced.
The distorted part of the copied or scanned image is
20   hard to read and, furthermore, a character
recognition rate of an OCR (optical character
reader) becomes very low. Above all, the thicker
the book is, the harder it is to read the copied or
scanned image. On the other hand, if the book is
25   pressed to the focus plane, the book may be damaged.

To address this problem, therefore, a method to correct a distorted image has been proposed, in which method a three dimensional shape of an object is estimated based on density

5 information of the image. An example of that method is described in a publication of T.Wada, H.Uchida and T.Matuyama, " Shape from Shading with Interreflection under a Proximal Light Source: Distortion-Free Copying of an Unfolded Book",

10 International Journal Computer Vision 24(2), 125-135(1997) and the representative method of shape from shading is further described in a publication of Hiroyuki Ukita and Katsunobu Konishi, "Three dimensional shape recovery for a booklet surface

15 using intrinsic space method", IECE technical report, PRMU99-91, pp.23-30, Oct., 1999.

Further, a method is proposed in the laid-open Japanese patent application number 11-41455, in which method a three dimensional shape of an object

20 is estimated based on an outline of a scanned image.

However, it is hard to put the method called the shape from shading into practical use because the method requires significant computational steps, and therefore requires a

25 computational time of long duration.

On the other hand, a method described in the laid-open Japanese patent application number 11-41455 only requires a few computational steps to correct the distorted image, however, it is

5 difficult to sufficiently correct the distorted image using this method when the whole outline of the booklet is not fully captured.

SUMMARY OF THE INVENTION

10 It is a general object of the present invention to provide an image distortion correction apparatus, which is able to correct a distorted image and requires a few computational steps even if the whole outline of a booklet is not fully captured.

15 The above objects of the present invention are achieved by an image distortion correction apparatus comprising:

a circumscribed rectangle extraction unit which extracts a circumscribed rectangle for each

20 character in a distorted image scanned by an image reading unit from an original book placed on a reference plane;

a character string extraction unit which extracts character strings using the circumscribed

25 rectangles extracted by the circumscribed rectangle

extraction unit;

a distance estimation unit which estimates a distance between the reference plane and the original book containing the character strings; and

5   an image distortion correction unit which corrects the distorted image based on the distance between the reference plane and the original. estimated by the image distortion correction unit.

According to the invention, the character
10   strings are extracted from the scanned image read by an image reading unit. Then, a three dimensional shape (including a distance between the reference plane and the original) of the original, estimated based on the character strings and the image
15   distortion, is corrected. As a result, even if the whole outline of the booklet is not fully captured, it is possible to sufficiently correct the distorted image with a few computational steps according to the present invention.

20   The above objects of the present invention are achieved by the image distortion correction apparatus further comprising:

an original distinction unit, which decides whether the original is written horizontally
25   or vertically, and in case wherein the original

distinction unit decides that the original is
written in the horizontal,

the distance estimation unit first selects
character strings each of which has a length longer
5   than a length equal to a predetermined ratio
multiplied by the length of the longest string out
of a plurality of character strings in the distorted
image, then, selects one string having the largest
curvature out of the selected character strings for
10 a reference character string, and then, estimates a
distance between the reference plane and the
original using the reference character string.

According to the invention, it is possible
to select a reference character string so that the
15 distance between the reference plane and the
original can be adequately estimated.

The above objects of the present invention
are achieved by the image distortion correction
apparatus, wherein the curvature is measured based
20 on a location of center coordinates in a main
scanning direction of the circumscribed rectangles
in the character string, and the larger a difference
between a maximum value of the center coordinates
and a minimum value of the center coordinates, the
25 larger is the curvature.

According to the present invention, it is possible to select the string having the largest curvature.

The above objects of the present invention

5   are achieved by the image distortion correction apparatus further comprising:

an original distinction unit which decides whether the original is written horizontally or vertically, andin case wherein the original

10 distinction unit decides that the original is written in the vertical,

the character string extraction unit extracts a reference character string using circumscribed rectangles either at a top of or at a

15 bottom of each vertical line,

the distance estimation unit estimates a distance between the reference plane and the original using the reference string.

According to the invention, it is possible

20 to select a reference character string so that the distance between the reference plane and the original can be adequately estimated.

The above objects of the present invention are achieved by the image distortion correction

25 apparatus, wherein

the distance estimation unit measures both a first distance D1 between a prolonged line of a straight line part in the reference character string and a curve part in the reference character string

5 and a second distance D2 between an imaging center straight line and the curve part in the reference character string, and estimates a distance D between the reference plane and the original based on

$$D = R \times (D1 / D2)$$

10 , where R is a distance between the reference plane and a center of a lens.

According to the present invention, the distortion is adequately measured and the three dimensional shape is properly estimated.

15 The above objects of the present invention are achieved by the image distortion correction apparatus, wherein

the distance estimation unit independently estimates each distance between the reference plane

20 and the original for a left page and a right page.

According to the present invention, in a case that each distance between the reference plane and the original for a left page and a right page has different value because, for example, the pages

25 near the first or last page of the original are

copied, each distance is independently estimated so that the distortion for each page is properly corrected.

an image distortion correction apparatus

5   comprising:

a ruled line extraction unit which extracts ruled lines in a distorted image scanned by an image reading unit to read an original placed on a reference plane;

10   a distance estimation unit which estimates a distance between the reference plane and the original using the ruled lines; and

an image distortion correction unit which corrects the distorted image based on the distance

15   between the reference plane and the original estimated by the image distortion correction unit.

According to the present invention, the ruled lines are extracted from the scanned image read by an image reading unit. Then, a three

20   dimensional shape (incorporating a distance between the reference plane and the original) of the original is estimated based on the ruled lines and the image distortion is corrected based on the estimated three dimensional shape of the original.

25   As a result, even if the whole outline of the

booklet is not fully captured, it is possible to
sufficiently correct the distorted image with a few
computational steps according to the present
invention.

5   The above objects of the present invention
are achieved by the image distortion correction
apparatus further comprising:

an original distinction unit which decides
whether the original is written horizontally or
10   vertically, wherein in case that the original
distinction unit decides that the original is
written in the horizontal,

the distance estimation unit first,
selects ruled lines each of which has a length
15   longer than a length of a predetermined ratio to
that of the longest ruled line out of a plurality of
ruled lines in the distorted image, then, selects
one ruled line placed nearest an upper edge or a
lower edge of the scanned image out of the selected
20   ruled lines for a reference ruled line, and then,
estimates a distance between the reference plane and
the original using the reference ruled line.

According to the present invention, it is
possible to select an adequate ruled line string so
25   that the distance between the reference plane and

the original is adequately estimated.

The above objects of the present invention are achieved by the image distortion correction apparatus, wherein

5 the distance estimation unit measures both a first distance D1 between a prolonged line of a line part in the reference ruled line and a curve part in the reference ruled line and a second distance D2 between an imaging center line and the

10 curve part in the reference ruled line, and estimates a distance D between the reference plane and the original based on

$$D = R \times (D1 / D2)$$

, where R is a distance between the reference plane

15 and a center of a lens.

According to the present invention, the distortion is adequately measured and the three dimensional shape is properly estimated.

The above objects of the present invention

20 are achieved by the image distortion correction apparatus, wherein

the distance estimation unit independently estimates each distance between the reference plane and the original for a left page and a right page.

25 According to the present invention, in

case that each distance between the reference plane and the original for a left page and a right page has different value because, for example, the pages near the first or last page of the original are

5 copied, each distance is independently estimated so that the distortion for each page is properly corrected.

The above objects of the present invention are achieved by a computer readable recording media

10 having a program to execute an image distortion correction method, the program comprising steps of:

a circumscribed rectangle extraction step for extracting a circumscribed rectangle for each character in a distorted image scanned by an image

15 reading step to read an original placed on a reference plane;

a character string extraction step for extracting character strings using the circumscribed rectangles extracted by the circumscribed rectangle

20 extraction step;

a distance estimation step for estimating a distance between the reference plane and the original using the character strings; and

an image distortion correction step for

25 correcting the distorted image based on the distance

between the reference plane and the original estimated by the image distortion correction step.

According to the present invention, the character strings are extracted from the scanned

5   image read by an image reading unit. Then, a three dimensional shape (a distance between the reference plane and the original) of the original is estimated based on the character strings and the image distortion is corrected based on the three

10   dimensional shape of the original. As a result, even if the whole outline of the booklet is not fully captured, it is possible to sufficiently correct the distorted image with a few computational steps according to the present invention.

15   The above objects of the present invention are achieved by the computer readable recording media further comprising:

an original distinction step which decides whether the original is written horizontally or

20   vertically, wherein in case that the original distinction unit decides that the original is written in the horizontal,

the distance estimation step first, selects character strings each of which has a length

25   longer than a length of a predetermined ratio to

that of the longest string out of a plurality of character strings in the distorted image, then, selects one string having the largest curvature out of the selected character strings for a reference

5 character string, and then, estimates a distance between the reference plane and the original using the reference string.

According to the present invention, it is possible to select an adequate reference character

10 string so that the distance between the reference plane and the original is adequately estimated.

The above objects of the present invention are achieved by the computer readable recording media, wherein the curvature is measured based on a

15 location of a center coordinates in a main scanning direction of the circumscribed rectangle in the character string, and the larger a difference between a maximum value of the center coordinates and a minimum value of the center coordinates, the

20 larger the curvature is.

According to the present invention, it is possible to select the string having the largest curvature.

The above objects of the present invention

25 are achieved by the computer readable recording

media further comprising:

an original distinction step for deciding whether the original is written horizontally or vertically, wherein in case that the original

5 distinction unit decides that the original is written in the vertical,

the character string extraction step extracts a reference character string using circumscribed rectangles either at a top of or at a

10 bottom of each vertical line,

the distance estimation step estimates a distance between the reference plane and the original using the reference string.

According to the present invention, it is

15 possible to select an adequate reference character string so that the distance between the reference plane and the original is adequately estimated.

The above objects of the present invention are achieved by the computer readable recording

20 media, wherein

the distance estimation step measures both a first distance D1 between a prolonged line of a line part in the reference character string and a curve part in the reference character string and a

25 second distance D2 between an imaging center line

and the curve part in the reference character string, and estimates a distance D between the reference plane and the original based on

$$D = R \times (D1 / D2)$$

5   , where R is a distance between the reference plane and a center of a lens.

According to the present invention, the distortion is adequately measured and the three dimensional shape is properly estimated.

10   The above objects of the present invention are achieved by the computer readable recording media, wherein

the distance estimation step independently estimates each distance between the reference plane

15   and the original for a left page and a right page.

According to the present invention, in case that each distance between the reference plane and the original for a left page and a right page has different value because, for example, the pages

20   near the first or last page of the original are copied, each distance is independently estimated so that the distortion for each page is properly corrected.

The above objects of the present invention

25   are achieved by a computer readable recording media

having a program to execute an image distortion
correction method, the program comprising steps of:

a ruled line extraction step for
extracting ruled lines in a distorted image scanned
5 by an image reading unit to read an original placed
on a reference plane;

a distance estimation step for estimating
a distance between the reference plane and the
original using the ruled lines; and

10 an image distortion correction step for
correcting the distorted image based on the distance
between the reference plane and the original
estimated by the image distortion correction step.

According to the present invention, the
15 ruled lines are extracted from the scanned image
read by an image reading unit. Then, a three
dimensional shape (a distance between the reference
plane and the original) of the original is estimated
based on the ruled lines and the image distortion is
20 corrected based on the three dimensional shape of
the original. As a result, even if the whole
outline of the booklet is not fully captured, it is
possible to sufficiently correct the distorted image
with a few computational steps according to the
25 present invention.

The above objects of the present invention are achieved by the computer readable recording media further comprising:

an original distinction step for deciding

5   whether the original is written horizontally or vertically, wherein in case that the original distinction unit decides that the original is written in the horizontal,

the distance estimation step first,

10   selects ruled lines each of which has a length longer than a length of a predetermined ratio to that of the longest ruled line out of a plurality of ruled lines in the distorted image, then, selects one ruled line placed nearest an upper edge or an

15   lower edge of the scanned image out of the selected ruled lines for a reference ruled line, and then, estimates a distance between the reference plane and the original using the reference ruled line.

According to the present invention, it is

20   possible to select a ruled line string so that the distance between the reference plane and the original is adequately estimated.

The above objects of the present invention are achieved by the computer readable recording

25   media, wherein

the distance estimation step measures both a first distance D1 between a prolonged line of a line part in the reference ruled line and a curve part in the reference ruled line and a second

5   distance D2 between an imaging center line and the curve part in the reference ruled line, and estimates a distance D between the reference plane and the original based on

$$D = R \times (D1 / D2)$$

10   , where R is a distance between the reference plane and a center of a lens.

According to the present invention, the distortion is adequately measured and the three dimensional shape is properly estimated.

15   The above objects of the present invention are achieved by the computer readable recording media, wherein

the distance estimation step independently estimates each distance between the reference plane

20   and the original for a left page and a right page.

According to the present invention, in case that each distance between the reference plane and the original for a left page and a right page has different value because, for example, the pages

25   near the first or last page of the original are

copied, each distance is independently estimated so that the distortion for each page is properly corrected.

The above objects of the present invention

5   are achieved by an image distortion correction method comprising steps of:

a circumscribed rectangle extraction step for extracting a circumscribed rectangle for each character in a distorted image scanned by an image

10   reading step to read an original placed on a reference plane;

a character string extraction step for extracting character strings using the circumscribed rectangles extracted by the circumscribed rectangle

15   extraction step;

a distance estimation step for estimating a distance between the reference plane and the original using the character strings; and

an image distortion correction step for

20   correcting the distorted image based on the distance between the reference plane and the original estimated by the image distortion correction step.

According to the present invention, the character strings are extracted from the scanned

25   image read by an image reading unit. Then, a three

dimensional shape (a distance between the reference plane and the original) of the original is estimated based on the character strings and the image distortion is corrected based on the three

5 dimensional shape of the original. As a result, even if the whole outline of the booklet is not fully captured, it is possible to sufficiently correct the distorted image with a few computational steps according to the present invention.

10   The above objects of the present invention are achieved by an image distortion correction method comprising steps of:

a ruled line extraction step for extracting ruled lines in a distorted image scanned

15 by an image reading unit to read an original placed on a reference plane;

a distance estimation step for estimating a distance between the reference plane and the original using the ruled lines; and

20   an image distortion correction step for correcting the distorted image based on the distance between the reference plane and the original estimated by the image distortion correction step.

According to the present invention, the

25 ruled lines are extracted from the scanned image

read by an image reading unit. Then, a three
dimensional shape (a distance between the reference
plane and the original) of the original is estimated
based on the ruled lines and the image distortion is

5 corrected based on the three dimensional shape of
the original. As a result, even if the whole
outline of the booklet is not fully captured, it is
possible to sufficiently correct the distorted image
with a few computational steps according to the

10 present invention.

The above objects of the present invention
are achieved by an image scanner comprising:

an image reading unit to read an original
placed on a reference plane; and

15 an image distortion correction apparatus
comprising;

a circumscribed rectangle extraction unit
which extracts a circumscribed rectangle for each
character in a distorted image scanned by the image

20 reading unit;

a character string extraction unit which
extracts character strings using the circumscribed
rectangles extracted by the circumscribed rectangle
extraction unit;

25 a distance estimation unit which estimates

a distance between the reference plane and the original using the character strings; and

an image distortion correction unit which corrects the distorted image based on the distance

5 between the reference plane and the original estimated by the image distortion correction unit.

According to the present invention, the image scanner which sufficiently corrects the distorted image can be provided.

10 The above objects of the present invention are achieved by an image scanner comprising:

an image reading unit to read an original placed on a reference plane; and

an image distortion correction apparatus

15 comprising;

a ruled line extraction unit which extracts a ruled lines in a distorted image scanned by the image reading unit;

a distance estimation unit which estimates

20 a distance between the reference plane and the original using the ruled lines; and

an image distortion correction unit which corrects the distorted image based on the distance between the reference plane and the original

25 estimated by the image distortion correction unit.

According to the present invention, the image scanner which sufficiently corrects the distorted image can be provided.

The above objects of the present invention

5   are achieved by an image forming apparatus comprising:

an image reading unit to read an original placed on a reference plane;

an image distortion correction apparatus

10   comprising;

a circumscribed rectangle extraction unit which extracts a circumscribed rectangle for each character in a distorted image scanned by the image reading unit;

15   a character string extraction unit which extracts character strings using the circumscribed rectangles extracted by the circumscribed rectangle extraction unit;

a distance estimation unit which estimates

20   a distance between the reference plane and the original using the character strings; and

an image distortion correction unit which corrects the distorted image based on the distance between the reference plane and the original

25   estimated by the image distortion correction unit;

and,

a printing unit which prints the corrected image supplied from the image distortion correction apparatus on a paper.

5   According to the present invention, the image forming apparatus which sufficiently corrects the distorted image can be provided.

The above objects of the present invention are achieved by an image forming apparatus

10   comprising:

an image reading unit to read an original placed on a reference plane;

an image distortion correction apparatus comprising;

15   a ruled line extraction unit which extracts ruled lines in a distorted image scanned by the image reading unit;

a distance estimation unit which estimates a distance between the reference plane and the

20   original using the ruled lines; and

an image distortion correction unit which corrects the distorted image based on the distance between the reference plane and the original estimated by the image distortion correction unit;

25   and

a printing unit which prints the corrected image supplied from the image distortion correction apparatus on a paper.

According to the present invention, the

5   image forming apparatus which sufficiently corrects the distorted image can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of

10 the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

Fig.1 shows a sectional diagram of a

15 scanner part according to an embodiment of the present invention;

Fig.2 shows a perspective view of an upper part of an digital copy machine equipped with the scanner part according to an embodiment of the

20 present invention;

Fig.3 shows an electrical block diagram of a control system of the scanner part;

Fig.4 shows a basic block diagram of an internal construction of an image processing unit;

25 Fig.5 shows an electrical block diagram of

a main control unit;

     Fig.6 shows a flow chart of an image distortion correction process for a scanned image according to the present invention;

5   Fig.7 shows a perspective view of the scanner, on a contact glass of which a book type original is placed;

     Fig.8 shows an example of the scanned image;

10   Fig.9 shows a distorted part in the vicinity of a binding part of the book type original;

     Fig.10 shows a histogram of black pixels in the scanned image as shown in Fig.8;

15   Fig.11 shows a process to extract a circumscribed rectangle for each character;

     Fig.12 shows a principle of a Hough transformation;

     Fig.13 shows an extracted line from the character string as shown in Fig.11 using the Hough transformation;

20   Fig.14 shows an extracted curve from the character string as shown in Fig.11 using the least square method;

25   Fig.15 shows a distance between the line

and the curve of a reference character string;

Fig.16 shows a height between the a contact glass and the surface of a book type original;

5   Fig.17 shows a shrunk scanned image;

Fig.18 shows an imaging of the book type original on an imaging plane through a scanner lens;

Fig.19 shows a downward shift of a binding part in the scanned image of the book type original;

10   Fig.20 shows a reference character string in an original which is written vertically;

Fig.21 shows an example of a ruled line in a sub scanning direction;

Fig.22 shows an example of a corrected

15   image of which distortion is corrected according to the present invention;

Fig.23 shows the first embodiment of the selection of the reference character string according to the present invention;

20   Fig.24 shows the second embodiment of the selection of the reference character string according to the present invention;

Fig.25 shows the third embodiment of the selection of the reference character string

25   according to the present invention;

Fig.26 shows the fourth embodiment of the selection of the reference character string according to the present invention;

Fig.27 shows the fifth embodiment of the
5 selection of the reference ruled line according to the present invention;

Fig.28 shows the sixth embodiment of the selection of the reference ruled line according to
10 the present invention;

Fig.29 shows the seventh embodiment of the selection of the reference ruled line according to the present invention; and

Fig.30 shows the eighth embodiment of the selection of the reference ruled line according to
15 the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, an embodiment according to the present invention will be explained with reference
20 to Fig.1 to Fig.22. An image construction apparatus such as digital copy machine has an image distortion correction apparatus according to an embodiment of the present invention and an image scanner is a scanner part of the digital copy machine.

25 Fig.1 shows a sectional diagram of a

construction of a scanner part 1. As shown in Fig.1,
the scanner part 1 has a contact glass 2 on which an
original is placed, a first travelling assembly 5
having an exposure lamp 3 which exposes the original

5   1, a first reflection mirror 4, a second travelling
assembly 8 having a second reflection mirror 6 and a
third reflection mirror 7, an imaging device 9 such
as a CCD (a charge coupled device), a lens unit 10
which focuses the original on the imaging device 9,

10 an original scale 11 which is a reference for the
original and prevents the contact glass 2 from being
detached, a white board 12 which corrects shading
and is attached under the original scale 11, and a
frame 14. The CCD 9 is formed on a sensor board 13.

15   The first travelling assembly 5 and the
second travelling assembly 8 are driven by a
stepping motor 24 (refer to Fig.3) in the sub
scanning direction when the original is scanned.
The first travelling assembly 5 and the second

20 travelling assembly 8 carry the exposure lamp 3
under the contact glass 2 and the original is
exposed to light. The reflected light from the
original 1 is reflected by the first reflection
mirror 4, the second reflection mirror 6 and the

25 third reflection mirror 7 and then, is focused on

the CCD 9 through the lens unit 10.

The scanner part 1 is provided to the digital copy machine 16 which has a printer part (not shown) as an image forming apparatus that forms

5   an image on a paper using a electro photograph method according to the image data. Fig.2 shows a perspective view of an upper part of the digital copy machine 16 equipped with the scanner part 1. As shown in Fig.2, an original cover 17 which can be

10 opened and closed against the contact glass 2 and an open and close sensor 18 of the original cover 17 are provided to the scanner part 1. Alternative printers which employ various kinds of printing method, such as an electro photograph method, an ink

15 jet method, a dye sublimation thermoelectric method, a silver bromide photograph method, a direct thermal recording method and a melting thermoelectric method as well as the electro photograph method can be provided to the digital copy machine 16 as the

20 printer. Explanations of these methods are omitted because these methods are well known to those who are skilled in the art.

Fig.3 shows an electrical block diagram of a control system of the scanner part 1. In this

25 control system, a main control unit 19 is connected

to an image processing unit 20, a travelling

assembly control unit 21, an operation panel 22 and

a memory 23. The main control unit 19 controls the

whole of the scanner 1. The image processing unit

5   20 processes image data captured by the CCD 9. The

travelling assembly control unit 21 controls the

first travelling assembly 5 and the second

travelling assembly 8. The operation panel 22

receives commands supplied to the digital copy

10 machine 16 and displays various kinds of messages.

The memory 23 stores the image data captured by the

CCD 9 and other predetermined data. On the

operation panel 22, keys such as a copy start key

which initiates copying, and so on are provided.

15 The travelling assembly control unit 21 is connected

to the exposure lamp 3, the stepping motor 24 which

drives the first travelling assembly 5 and the

second travelling assembly 8, a scanner home

position sensor (an HP sensor) 25 which detects that

20 the first travelling assembly 5 and the second

travelling assembly 8 are placed at the home

position and the open and close sensor 18.

Fig.4 shows a basic block diagram of an

internal construction of the image processing unit

25 20. As shown in Fig.4, the image processing unit 20

has an analog video processing unit 26, a shading
correction processing unit 27 for the shading
correction, an image data processing unit 28 and an
image distortion correction unit 29. The analog

5   video processing unit 26 amplifies the image signal
captured by the CCD 9 and converts the captured
analog image into a digital image. The image data
processing unit 28 performs an MTF correction, a
scaling process and a γ correction to the shading

10 corrected digital image and produces a scanned image.
The image distortion correction unit 29 performs a
distortion correction for the distorted image, which
is a characteristic feature of the present invention.
The image processed digital image is supplied to the

15 printer part through the main control unit 19 and
then is printed out.

        Fig.5 shows an electrical block diagram of
the main control unit 19. As shown in Fig.5, the
main control unit 19 has a CPU (central processing

20 unit) 31 which centrally controls components
connected to it. This CPU 31 is connected to a ROM
(read only memory) 32 which stores BIOS, and so on,
a RAM (random access memory) 33 which serves as a
work area for the CPU 31, and a bus 34. These

25 components compose a micro computer. Further, the

bus 34 is connected to a HDD which stores a control program, a CD-ROM (Compact Disc) drive 36 which reads a CD-ROM 37 and an interface (I/F) 38 through which the CPU 31 communicates with the printer part.

5   The CD-ROM 37 as shown in Fig.5 is one of the recording media of the present invention and stores a predetermined control program. The CPU 31 reads the control program stored on the CD-ROM 37 through the CD-ROM drive 36 and then installs it to

10   the HDD 35. This program enables the main control unit 19 to perform various processes which are described later.

          Further, it is possible to use various kinds of optical discs such as DVD's, various kinds

15   of magnet-optical discs, various kinds of magnet discs such as floppy discs, various kinds of semiconductor memories, and so on, as well as the CD-ROM 37 as the recording media. It is also possible to install the program, which is downloaded

20   through networks such as the Internet, to the HDD 35. In this case, the recording media which store the programs on a server side are also the recording media according to the present invention. The program may be executed under a predetermined OS

25   (Operating System) or the OS may execute a part of

the processes in the program, as described later.
Further, the program may be included in a group of
program files which construct application programs
such as word processing software and an operating
5 system, and so on.

Processes which are executed by the CPU 31
provided in the main control unit 19 under the
control of the control program, will be explained.
First of all, a distortion correction process for a
10 scanned image executed by the image distortion
correction unit 29 will be explained. This process
corrects the scanned and distorted image and is a
characteristic function of the scanner part 1
according to the present invention.

15 Fig.6 shows a schematic flow chart of the
distortion correction process for the scanned image
according to the present invention. Fig.7 shows a
perspective view of the scanner part, on a contact
glass of which a book type original 40 is placed.
20 The binding part 41 of the book type original 40 is
placed on the contact glass 2 in parallel to a main
scanning direction of the scanner part 1.

First, at a step S1, the scanned image of
the book type original 40 on the contact glass 2
25 output from the image data processing unit 28 is

supplied to the image distortion correction unit 29.
Fig.8 shows an example of the scanned image. Fig.9
shows a distorted part in the vicinity of a binding
part 41 of the book type original 40. As shown in
5   Fig.9, the scanned image has the distortion part in
the vicinity of the binding part 41.

Next, at a step S2, the scanned image of
the book type original 40, for example, a gray scale
image, is optimally converted into a binary image.
10 Then, at a step S3, a histogram of a number of black
pixels in the sub scanning direction is calculated.
The black pixel is a pixel with higher density than
a predetermined density. Fig.10 shows a histogram
of the black pixels in the scanned image as shown in
15 Fig.8. A horizontal axis in Fig.10 shows a position
of the black pixel in the sub scanning direction,
and a vertical axis in Fig.10 shows the number of
the black pixels.

Next, at a step S4, the process waits
20 until an instruction is received, which shows
whether the image distortion correction process is
performed based on character information or ruled
line information.

If the instruction received shows that the
25 character information is used for the image

distortion correction process (N at the step 4),
then the process advances to a step 5. In the step
5, it is determined whether the characters in the
book type original are written vertically or

5   horizontally. This determination is done based on
the histogram of the number of the black pixels in
the sub scanning direction calculated in the step 3.
For example, if the original is written in the
horizontal as shown in Fig. 8, there exists a

10 repetition pattern of peaks. On the other hand, in
case of that the original is written in the vertical,
there is no repetition pattern of the peaks. This
characteristic enables to decide whether an original
is written in horizontally or vertically.

15   If the scanned image is a color gray scale
image, the conversion of the scanned image into the
binary image is performed using one component among
R (red), G (green) and B (blue) components, for
example, the G component. In this case, the black

20 pixel is a pixel of the G component with higher
density than a predetermined density of the G
component and the white pixel is a pixel of the G
component with lower density than a predetermined
density of the G component. It is also possible to

25 decompose the RGB image into a luminance component

and a chrominance component, and then the luminance
component can be used to convert the scanned image
into the binary image, as mentioned above.

In case that the original is written in
5   the horizontal (Y at the step S5), a character
string extraction process extracts a circumscribed
rectangle for each character, which is a series of
the black pixels, at a step 6. Then, at a step 7, a
plurality of character strings are extracted and an
10   optimal reference character string is selected among
the character strings. An explanation of the
character recognition process is omitted because it
is well known. Fig.11 shows an example of a result
of the string extraction process to extract a
15   circumscribed rectangle for each character and the
selected optimal character string. The optimal
character string is a string which has a length
longer than a predetermined length and has the
largest curvature among the plurality of character
20   strings. For example, the string which has the
length longer than the predetermined length is a
string having a length longer than 80 % of the
longest string. An optimal character string is
selected for each side of a border of the binding
25   part 41 of the book type original 40. The curvature

is measured based on a location of the center
coordinates in the main scanning direction of the
circumscribed rectangle in the character string.
The larger a difference between the maximum value of
5 the center coordinates and the minimum value of the
center coordinates, the larger is the curvature.

Next, at a step S8, a line portion in the
optimal reference character string selected at the
step S7 is extracted. The extraction of the line
10 portion in the optimal reference character string is
performed using a Hough transformation of the center
coordinates of each circumscribed rectangle.

A principal of the Hough transformation
will be explained. Fig.12 shows the principle of a
15 Hough transformation. A line on a point P(x, y)
satisfies the equation (1) as follows.

$$\rho = x \cdot \cos\theta + y \cdot \sin\theta \qquad (1)$$

where (x, y) are the coordinates of the point P and
ρ is a distance between the origin and the point P.
20 θ is an angle between a line segment PO and the x-
axis. The center coordinates (xi, yi) of the
rectangle are projected to (ρ, θ) a discrete
(meshed) parameter plane. A point (x, y) is
projected to one curve on the (ρ, θ) plane. A
25 count value for each mesh on the curve is

incremented. If there is a point having a large
count value on the (ρ, θ) plane, there exists a
corresponding line on the (x, y) plane. Therefore,
the line on the (x, y) plane can be extracted by
5   means of finding a point having the largest count
value on the (ρ, θ) plane because there is only one
line for each character string. This method is
robust against a noise and, it is possible to
extract a line even if a line and a curve co-exist.
10   Fig.13 shows an extracted line from the character
string as shown in Fig.11 using the Hough
transformation.

Next, at a step S9, a curve part in the
reference character string is extracted. The
15   selected reference character string at the step S7
is approximated by a polynominal (2) and
coefficients of the polynominal are calculated using
the least square method. That is to say, the step
S9 calculates an approximated curve for the selected
20   reference character string.

$$Y=a_0+a_1x^1+ a_2x^2+ \cdot \ \ \cdot \cdot + a_nx^n \qquad (2)$$

,where (x, y) are the center coordinates of the
circumscribed rectangle and $(a_0, a_1, a_2, \cdot \ \ \cdot \cdot a_n)$
are the coefficients of the polynominal. Fig.14
25   shows an extracted curve from the character string

as shown in Fig.11 using the least square method.

Next, at a step S10, a distance between the line calculated at the step S8 and the curve calculated at the step S9 is measured. Then a three dimensional shape recovery is performed at a step S11. Fig.15 shows the distance between the line and the curve in a reference character string.

In case that the binding part 41 of the book type original 40 is placed on the contact glass 2 in parallel to a main scanning direction of the scanner part 1, the characteristics of the image formation system are as follows when the lens unit 10 is used to read the book type original 40. The image formation system uses a center projection in the main scanning direction and it uses a plain projection in the sub scanning direction. The three dimensional shape recovery uses these characteristics. Fig.16 shows a height between the a contact glass 2 and the surface of a book type original. Fig.17 shows a shrunk scanned image. As shown in Fig.16 and Fig.17, in a case of center projection, the greater the distance d between the contact glass 2 and the surface of a book type original 40 becomes, the lower the magnification of the image becomes. Therefore, upper and lower lines

of an outline of the scanned image of the book type
original 40 are curved to the inside as shown in
Fig.17. This means that it is possible to calculate
a height d based on a measured value of the distance
5   AB. As a result, it is possible to recover the
three dimensional shape, that is to say, the
distance d between the contact glass 2 and the
surface of a book type original 40, based on the
measured value of the distance AB.

10   It is assumed that the book type original
40 is placed horizontally on the contact glass 2.
Then, the three dimensional shape is observed as a
two dimensional shape. Fig.18 shows an imaging of
the book type original 40 on an imaging plane
15 through a scanner lens. A reference OO' shows an
optical axis and a reference O shows a center of the
lens. A reference F shows a distance between the
contact glass 2 as a reference plane of the scanner
and the center of the lens O and this distance is
20 called a focal length of the scanner. A point B on
the reference plane of the scanner forms an image D
on the imaging plane. A point C on the book type
original 40 separated from the reference plane of
the scanner forms an image E on the imaging plane.
25 A distances between the point E and the center O is

y and a distances between the point D and the center

O is y'. It is noted that the center of the lens is

moved when the first travelling assembly 5 and the

second travelling assembly 8 are moved in the sub

5   scanning direction. We call the trace of the center

of the lens an imaging center line. Relation among

d, F, AB, AO', y and y' satisfy following equations

(3) and (4) using the similar triangles.

$$d/F = AB/AO' \qquad (3)$$

10    $$AB/AO' = (y'-y)/y \qquad (4)$$

A distance d is obtained from the

equations (3) and (4) based on a following equation

(5).

$$d = F \times ((y'-y)/y) \qquad (5)$$

15   The three dimensional shape can be

obtained from the equation (5) based on the value

(y' - y) which shows a two dimensional distortion

value. In this embodiment, the dimensional

distortion value (y' - y) and the distance y are

20   obtained from the line part and curve part extracted

from the reference character string as mentioned

above or the ruled line. The focal length F is

fixed to the scanner part 1 and is known value. A

set value of the scanner part 1 or a calibrated

25   value for the lens is used for the focal length F.

The distance between the reference plane of the scanner and the surface of the book type original 40 is determined by means of the steps S8 to S11 as mentioned above.

5   Next, at a step S12, a distortion correction of the scanned image is performed based on the three dimensional shape determined by the above steps. Then, at a step S13, the luminance of the corrected image is corrected. Fig.19 shows a

10   downward shift of a binding part in the scanned image of the book type original. The scanned image is shifted, row by row, downward in parallel to the binding part of the book original until the lower edge of the scanned image becomes straight. Then, a

15   reduction ratio is calculated based on a distance between a dotted straight line and an upper curve edge of the scanned image and the scaling process is performed to the scanned image. Further, the scanned image is expanded in the sub scanning

20   direction. Further, the luminance correction is performed for each pixel in each column based on the whitest pixel in the column. More details are described in the laid-open Japanese patent application number 11-41455. The image distortion

25   correction is performed by means of the steps   S12

and S13 mentioned above.

Next, another embodiment of the present invention will be explained. Fig.20 shows a reference character string in a case that an
5 original is written in vertically. When it is determined that the character string in the original is written in the vertical at the step S5 (N), an extraction process of the circumscribed rectangle and an extraction process of the character string
10 written vertically are performed at a step S14. A circumscribed rectangle at a top of or at a bottom of each vertical line is extracted and a reference character string is determined based on the circumscribed rectangles. Then, the envelope of the
15 vertical lines is extracted based on the reference character string.

Next, at the step S8 to S13, the image distortion correction process is performed using the center coordinates of each circumscribed rectangle
20 in the reference character string as mentioned above.

It is also possible to use ruled lines in the sub scanning direction to perform the image distortion correction process when the indication to select ruled line information is supplied at the
25 step S4 (Y). At a step S15, the ruled line in the

sub scanning direction is extracted. Fig.21 shows

an example of a ruled line in the sub scanning

direction. The histogram of the black pixels in the

sub scanning direction calculated at the step S3 is

5   used at the step S15. AS shown in Fig.21, when

there are ruled lines in the scanned image, the

histogram has narrow peaks. Therefore, the peaks

are used to extract the ruled lines. The lines each

of which has a length longer than a predetermined

10   length are selected. For example, the ruled lines

which have the length longer than the predetermined

length are ruled lines having a length longer than

80 % of the longest ruled line. Then, one line

nearest the upper or lower edge of the scanned image

15   is selected as a reference ruled line. The

reference ruled line is selected for each side of a

border of the binding part 41 of the book type

original 40. Then, the same steps S8 to S13 as

mentioned above follow the step 15.

20   Fig.22 shows an example of a corrected

image of which distortion is corrected according to

the embodiment of the present invention. As shown

in Fig.22, the distortion in the vicinity of the

binding part 41 of the book type original 40 as

25   shown in Fig.8 is corrected.

Next, the embodiments for selection of the reference character string will be explained.

Fig.23 shows the first embodiment of the selection of the reference character string

5 according to the present invention. In this embodiment, first, strings each of which has a length longer than a length of a predetermined ratio to that of the longest string are selected out of a plurality of character strings. Then, one string

10 having the largest curvature out of the selected character strings is selected for the reference character string.

Fig.24 shows the second embodiment of the selection of the reference character string

15 according to the present invention. In this embodiment, first, strings each of which has a length longer than a length of a predetermined ratio to that of the longest string are selected out of a plurality of character strings. Then, one string

20 placed nearest the upper edge of the scanned image out of the selected character strings is selected for the reference character string.

Fig.25 shows the third embodiment of the selection of the reference character string

25 according to the present invention. In this

embodiment, first, strings each of which has a
length longer than a length of a predetermined ratio
to that of the longest string are selected out of a
plurality of character strings. Then, one string
5   placed nearest the lower edge of the scanned image
out of the selected character strings is selected
for the reference character string.

Fig.26 shows the fourth embodiment of the
selection of the reference character string
10 according to the present invention. In this
embodiment, first, strings each of which has a
length longer than a length of a predetermined ratio
to that of the longest string are selected out of a
plurality of character strings. Then, one string
15 placed nearest the binding part of a book type
original out of the selected character strings is
selected for the reference character string.

Next, the embodiments for selection of the
reference ruled line will be explained.
20   Fig.27 shows the fifth embodiment of the
selection of the reference ruled line according to
the present invention. In this embodiment, first,
ruled lines each of which has a length longer than a
length of a predetermined ratio to that of the
25 longest ruled line are selected out of a plurality

of ruled lines. Then, one ruled line having the largest curvature out of the selected ruled lines is selected for the reference ruled line.

Fig.28 shows the sixth embodiment of the
5 selection of the reference ruled line according to the present invention. In this embodiment, first, ruled lines each of which has a length longer than a length of a predetermined ratio to that of the longest ruled line are selected out of a plurality
10 of ruled lines. Then, one ruled line placed nearest the upper edge of the scanned image out of the selected ruled lines is selected for the reference ruled line.

Fig.29 shows the seventh embodiment of the
15 selection of the reference ruled line according to the present invention. In this embodiment, first, ruled lines each of which has a length longer than a length of a predetermined ratio to that of the longest ruled line are selected out of a plurality
20 of ruled lines. Then, one ruled line placed nearest the lower edge of the scanned image out of the selected ruled lines is selected for the reference ruled line.

Fig.30 shows the eighth embodiment of the
25 selection of the reference ruled line according to

the present invention. In this embodiment, first, ruled lines each of which has a length longer than a length of a predetermined ratio to that of the longest ruled line are selected out of a plurality

5 of ruled lines. Then, one ruled line placed nearest the binding part of a book type original out of the selected ruled lines is selected for the reference ruled line.

In the foregoing specification, the

10 invention has been described with reference to specific embodiments in which the image distortion correction unit is provided in the digital copy machine 16 as the digital image forming apparatus and an distorted image scanned by the scanner part 1

15 is corrected. However, it should be noted that the present invention is not limited to these embodiments. It will be evident that various modifications and changes may be made without departing from the spirit and scope of the invention.

20 For example, an image scanner which has an image reading means for an original may be connected to a personal computer and the personal computer loads a program stored on the CD-ROM 37 into the HDD in the personal computer. This construction achieves an

25 image distortion correction unit which operate as

mentioned above. It is also possible to correct the
distorted image, which has been already scanned by
another scanner, by means of the personal computer
of which the program stored on the CD-ROM 37 is

5   loaded into the HDD.

The present application is based on
Japanese priority application No.2000-379895 filed
on December 14, 2000, Japanese priority application
No.2001-101279 filed on March 30, 2001, and Japanese

10   priority application No.2001-374490 filed on
December 07, 2001, the entire contents of which are
hereby incorporated by reference.

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